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Ontario Department
of Education

1970
Senior Division

ELEMENTS
OF
COMPUTER
TECHNOLOGY

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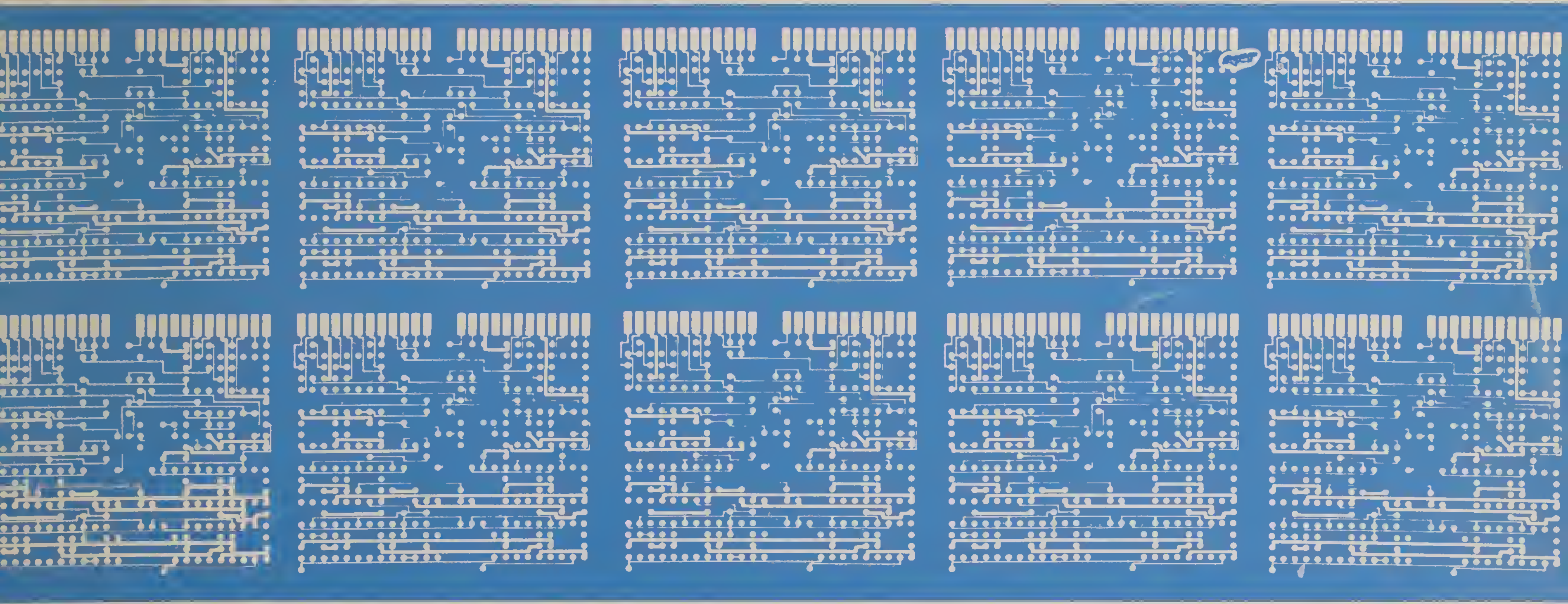

Elements of Computer Technology

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The experience of industry has been a major guide in developing this initial document. Future curriculum guides in this subject area will be built on successful teaching experiences. Teachers who prepare and implement courses within the scope of this guideline are invited to communicate with their Regional Program Consultant (Technical and Industrial Arts) or correspond directly with the Superintendent of Curriculum, Ontario Department of Education, Queen's Park, Toronto.

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Foreword

This document contains suggestions and recommendations for developing courses related to the technology of computers.

It is becoming increasingly important that every student acquire at least a basic knowledge of the computer, if only to remove some of the mystery which many people attribute to it. The computer and its systems are now common in many aspects of modern life, from banking to credit buying and space technology. An understanding of both the capabilities and the limitations of electronic computers is becoming invaluable.

The knowledge necessary to use the computer and to appreciate its capabilities and limitations can be acquired at different levels to meet different needs — from the junior operator who feeds the machine through the technician who understands basic programming and the electronics by which the machine operates to the software designer who requires a broad understanding of the intricacies of programming and systems design and the sophisticated techniques that may be used in each of these.

A full course in Elements of Computer Technology would offer the student activity in all the facets of computer study indicated in the organization summary (page 7), and would require three hundred to six hundred hours spread over two senior years.

Short courses could explore any one or more of the divisions of study and be as short as sixty hours. The chart on page 18 suggests several courses that could be established.

Two guidelines relating to computers have already been provided for Ontario schools. These are Data Processing and Computer Science. In Data Processing, emphasis is given to the programming of business applications and to systems design. Computer Science deals primarily with algorithms and aims to improve student skills in problem-solving. This new guideline, Elements of Computer Technology, is concerned with electronic circuitry, logic elements, peripheral equipment, and applications that assist in understanding the operation of a computer.

In the study of Elements of Computer Technology, the student should ideally receive a balanced program selected from the five divisions described in this outline. In this context 'balanced' means that all divisions are given some consideration but the amount of time spent on each varies. For example, experience suggests that the relative time devoted to circuitry and programming should be greater than that spent on the other three divisions.

Division 2 (Circuitry) and parts of other divisions could be taught in a conventional electronics shop; programming and the remainder of the course would likely require a special computer shop or laboratory. Thus, two or more teachers might be involved as a team in integrating the program.

Objectives

Elements of Computer Technology should be regarded primarily as an educating vehicle and not as a training program for technicians. The student should obtain an insight into the potential of computers, where they may be used, and how they function. The following may be considered as a list of objectives:

- to offer a suitable technical discipline for students expressing an *interest* in the technology of computers
- to provide a vehicle for further developing the *thought processes* of analysis, synthesis, and problem-solving
- to promote an understanding of the *fundamental principles* involved in processing data by electronic means
- to provide an additional vehicle for developing *knowledge and skills* in the general field of *electronics*
- to offer an *over-all introduction* to computing equipment and techniques as a broad base upon which the student may *evaluate a possible career* in the industry
- to present basic *principles of logic* which have eventual application in many decision-making situations
- to contribute toward the student's qualifications for *further training* and *employment* in the fields of computer technology and electronics.

A study that allows these objectives to be reached is both relevant and interdisciplinary; the technical depth may be adjusted to the level and competence of the students.

Organization

Division 1 Programming
Computer Organization
Flow Charting
Low-level Language Instructions
High-level Language Instructions
Number Systems

Division 2 Circuitry
Fundamental Circuits
Pulses
Information Storage
Logic Circuits
Indicators
Measuring Devices

Division 3 Computer Logic
Logic Elements
Logic Subsystems
Internal Data Flow
Observation of Circuit Operation

Division 4 Peripherals and Input-Output Devices
Basic Mechanisms: Mechanical and Electromechanical
Survey of Peripheral Devices
Computer Interfacing

Division 5 Computer Applications
Data Acquisition and Process Control
Problem-solving
Information Retrieval
Remote-Access Systems
Simulation and Operations Research

PDP-8/L

Division 1 Programming

Computer Organization
Flow Charting
Low-level Language Instructions
High-level Language Instructions
Number Systems

As a general topic, programming should include many aspects of computing. For example, students should have an understanding of computer organization and flow-charting methods before attempting to learn a programming language. Such studies need not be extensive but a study of computer organization should include discussion of the five basic functions of a computer: input, output, control, storage, and processing. With an understanding of these functions as a basis, any computer may be analyzed to determine how each of them is implemented.

A knowledge of flow-charting methods is essential for preparing a computer program, tracing a program, and applying testing techniques. A flow chart, being a pictorial representation of the solution of a problem, facilitates interpretation and understanding.

With an awareness of how a computer is organized and a comprehension of flow-charting methods, the student is ready to begin programming. It is suggested that he be introduced to both high-level and low-level languages. He does not need to master either type of language but it is important for him to understand the basic concepts of each. Low-level or machine languages have the distinct advantage of being closely associated with the way the machine actually does computations. Hence the mysteries that so often surround high-level languages can be dispelled by an understanding of a low-level language. The instruction set need not be extensive but should include branching and testing instructions so that the power of looping can be demonstrated.

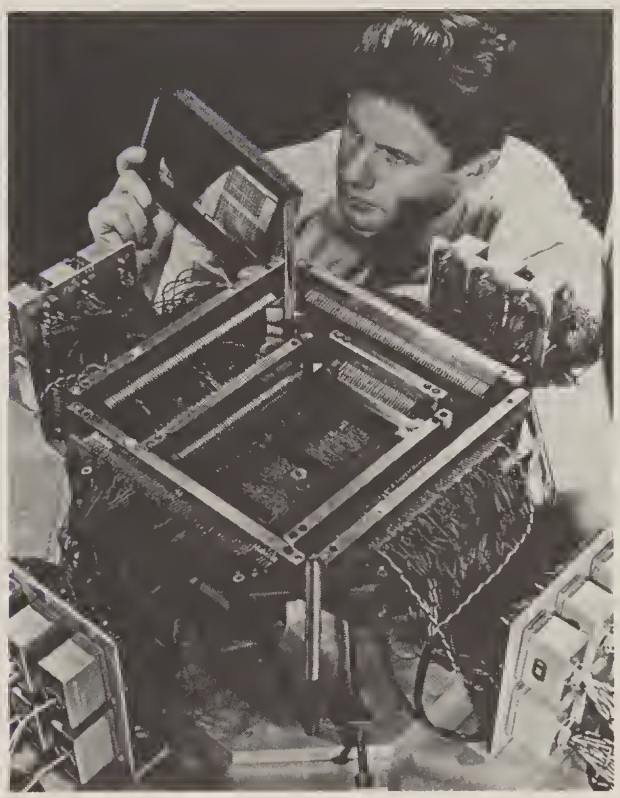
Learning a portion of high-level language is also important in order that the student might appreciate the role of compilers or assemblers in translating the high-level language to the low-level language that the machine ultimately requires. Also associated with languages are operating systems, supervisor routines, and monitors. The need for these will become obvious and their operating characteristics will become comprehensible once the student becomes acquainted with the different levels of languages.

Ultimately, computer instructions become electronic pulses that represent the information or data. If the student is to learn how the computer organizes these pulses through its many circuits to cause the machine to function, it is important that he understand all the steps involved in the translation of an instruction into electronic pulses. In this process of storing, sensing, moving, and operating with digital information, the student's comprehension will be helped considerably if he acquires an understanding of the basics of some number systems, notably binary, octal, and hexadecimal. It is not necessary that the student be able to perform all the arithmetic operations within each number system, but rather that he understand number systems to the point where he can readily interpret the coding structures used within the computer.

Division 2 Circuitry

Fundamental Circuits
Pulses
Information Storage
Logic Circuits
Indicators
Measuring Devices

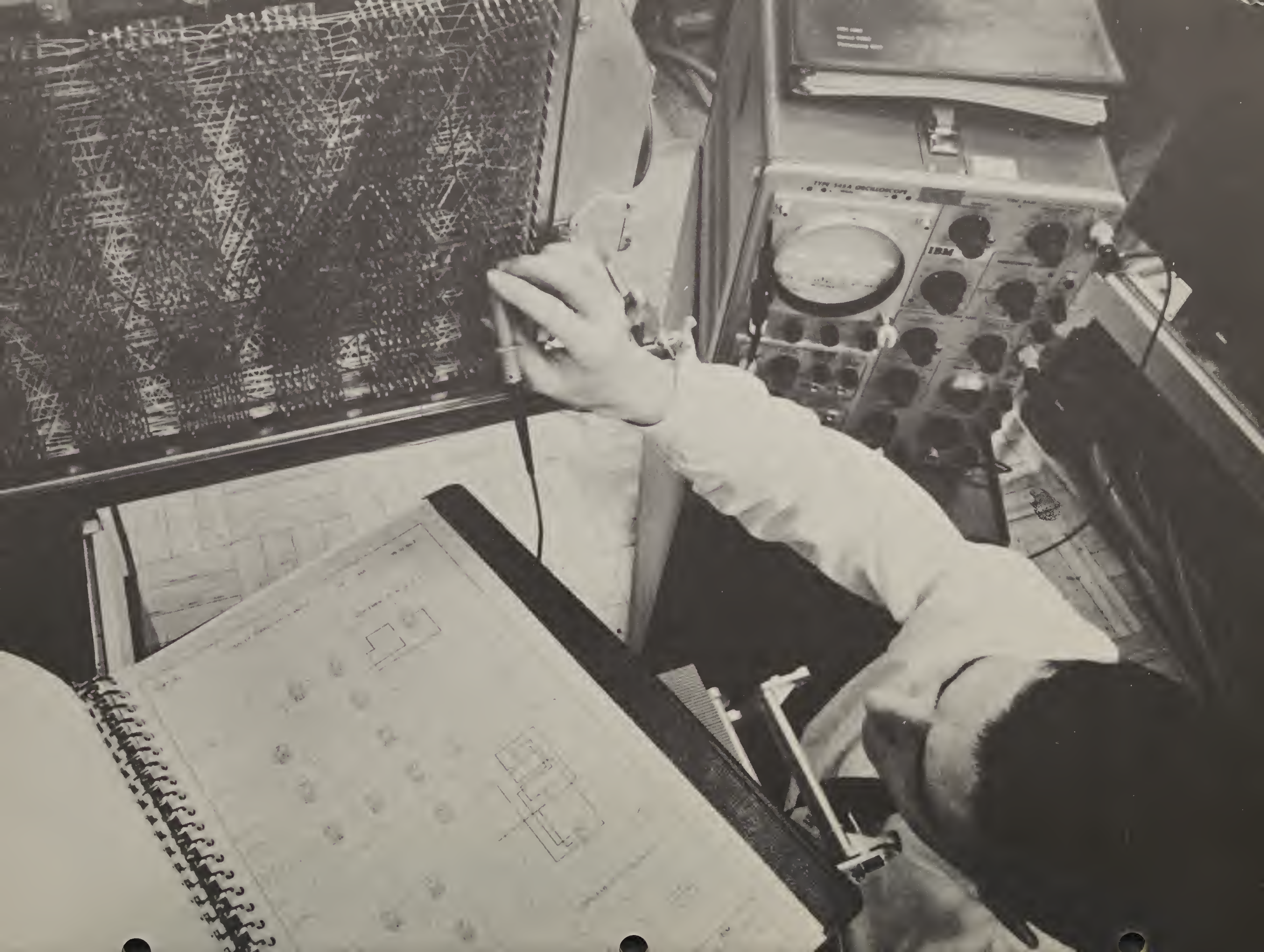
The student activities relating to this division include (a) an analysis of the operation of electronic circuits commonly employed in computers and (b) the design, construction, and maintenance of some of these circuits.



The emphasis in Division 2 is on the actual circuits and their modes of operation. This study will develop the student's grasp of electrical theory, his ability to interpret schematic diagrams and relate them to electronic apparatus, and his skill in the diagnosis of circuit or component faults.

Suitable hardware must be available to allow hands-on experience. Analysis of simple circuits, which can be constructed quickly, will increase the students' comprehension of the operation of integrated circuits. The study of more complex circuitry would be facilitated by the use of computers or computer subsystems that are constructed to permit measurement of operating conditions.

A computer technician or technologist must master the use of measuring instruments, particularly the oscilloscope. Some understanding of the circuits within the oscilloscope will improve his proficiency in the operation of that instrument.


TYPE 545A OSCILLOSCOPE
IBM

Division 3 Computer Logic

Logic Elements
Logic Subsystems
Internal Data Flow
Observation of Circuit Operation

The processing unit of a modern computing system is made up of combinations of several common types of basic logic elements. While the internal operation of these elements may vary among manufacturers and may change with advancing technology, the functions remain essentially the same. In general, element functions can be understood without detailed knowledge of their internal electronic circuits, although the studies of function and electronic structure tend to support each other. A single logic element may be made up of one or several transistors and/or diodes and perhaps two to ten resistors and capacitors.

Typical logic elements include "AND" circuits, "OR" circuits, invert circuits, flip-flops, latches, delay circuits, and single shots. This list is not complete but it will provide the basis for an understanding of almost any computing function.

Logic subsystems bring together a few of many logic elements in combinations that provide some specific processing functions such as translating (from one numbering system to another), comparing (are given numbers equal?), registering (active storage of numeric information), counting, binary adding, and timing.

The unit on internal data flow covers the relationship of various logic subsystems and shows how they handle data within a typical computer processing unit. Such a study is essential to demonstrate the application of the principles of logic previously studied.

The topics in this division lend themselves to assignments and laboratory activity ranging from the very basic to the very complex. It will be essential to have laboratory equipment available so that students may assemble operational logic subsystems from *logic elements,* not from circuit components. Since hands-on work should form the backbone of the Computer Logic Division, laboratory resources should be sufficient to enable all students to work on various practical assignments simultaneously. For the observation of circuit operation, oscilloscopes will be required.

Division 4 Peripherals and Input-Output Devices

Basic Mechanisms: Mechanical and Electromechanical
Survey of Peripheral Devices
Computer Interfacing

The aim of this division is to convey a knowledge of the operating principles of basic mechanisms relating to computers. The student should learn that complex machines are merely the integration of relatively simple mechanisms and devices.

If electromechanical kits are available, they can be used to encourage creative expression in the construction of apparatus designed to perform desired operations. If used commercial peripherals are obtained, their operation may be studied in some depth. For example, an understanding of card-transport mechanisms, tape-transport devices, and disc-access mechanisms is essential for a comprehension of how the original data bits are introduced to the computer circuitry.

The peripheral devices described above are only a few of the many currently available. It is desirable to survey as many devices as possible so that the student will be aware of the current state of the development. For example, devices such as cathode ray tubes and light pens are in the forefront of peripheral equipment development and should be studied.

Connecting these devices to the mainframe equipment is called interfacing. Interfacing is an important topic especially since it may involve relating equipment manufactured by different firms. In fact, interface equipment and interfacing techniques are very often the most vital part of the entire system.

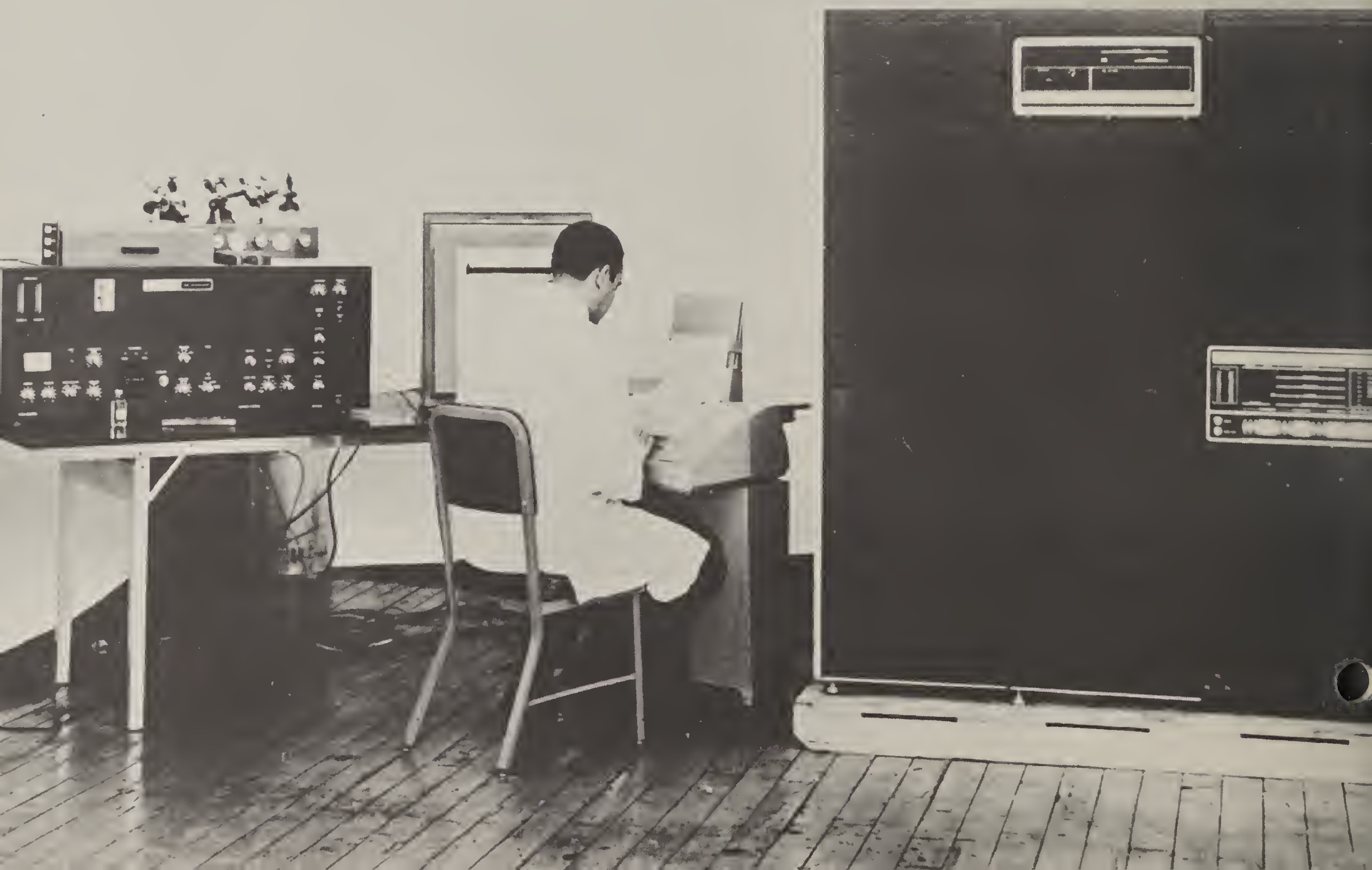
Since most computers provide for priority interrupts and cycle-stealing in order to interface with external peripheral devices, it is suggested that a particular and representative computer interface be described and then used as the basis for further discussion.

The basic characteristics of some typical peripheral devices should be described. For example, a paper tape reader and a magnetic tape unit could be used to illustrate some of the following characteristics:

Paper Tape:
- slow, from 10 to 1000 8-bit characters/sec
- can stop after reading a character and start under computer control.

Magnetic Tape:
- fast, typically 60,000 8-bit characters/sec
- cannot stop after each character but only at the end of a block of perhaps several hundred characters.

The use of buffering should be described to show how a peripheral device which presents data in a regular, synchronous fashion may be interfaced to a computer that must operate in an irregular, asynchronous fashion.



Division 5 Computer Applications

Data Acquisition and Process Control
Problem-solving
Information Retrieval
Remote-Access Systems
Simulation and Operations Research

The choice of emphasis in this section should depend upon the student who is taking the course.

For the student proceeding toward a career in computer technology, a study of computer applications illustrates the *raison d'être* for the computer industry and underlines the important role that computer specialists play in modern technological society. Attention should be given to the economic and technical considerations that dictate the choice of: general-purpose computer systems *vs.* special-purpose systems; local *vs.* remote-access systems; batch-processing *vs.* conversational systems; multi-programmed *vs.* one-job-at-a-time systems. A study of process-control applications will illustrate the need for specialized measuring and control devices that permit a computer to control a process without human intervention. A study of remote-access systems leads to discussion of data transmission equipment and methods. Current and projected developments in applications should be investigated from the point of view of innovations in computer design required to meet the anticipated user demands.

For the student proceeding to a field other than computer technology, the emphasis should be reversed. The goal of the course should be to provide the student with an appreciation of (a) the usefulness of computers in his future field of endeavour and the effect that computers will have in altering aspects of his field and (b) the role and effect of computer technology on society as a whole. The historical and projected developments in computer design should be studied from the point of view that technological developments determine the types of applications that are economically and technically feasible.

In either case, the student should obtain an overview of the following fields:

Data Acquisition and Process Control
data acquisition, automatic on-line supervision, and control of processes or operations.

Problem-solving
engineering design, development of scientific theory, analysis of experimental results, statistical tests, and forecasting.

Information Retrieval
data banks and multi-purpose files with business, industrial, or educational functions.

Remote-Access Systems
conversational computing and file-access.

Simulation and Operations Research
development of mathematical models for processes, hybrid simulations, pre-construction testing of designs, and optimization of operations.

Course	Content	Approximate Time	Accommodation
Elements of Computer Technology I An integrated technical course for the student who wishes to make a major study of computer technology. The electronics portion of the course would provide treatment of communications and industrial electronics, in addition to computer circuitry. The graduate could proceed to tertiary education (probably to a C.A.A.T.) or seek employment in the broad field of electronics and/or computers.	All divisions plus electronics major	Senior Division: two years 660 hours	Electronics Shop and Computer Laboratory (half time in each area)
Elements of Computer Technology II A form of integrated technical course intended for university-bound students. It might be taken in conjunction with Computer Science or Data Processing.	All divisions plus electronics major	Senior Division: two years 330 hours	Electronics Shop and Computer Laboratory (half time in each area)
Elements of Computer Technology III A survey course in which electronic circuitry is minimized, it is intended for the student who wants a basic understanding of the computer as a tool, without reference to circuit operation or maintenance.	Divisions 1, 3, 4 and 5	Senior Division: one year 110 hours	Computer Laboratory
Computer Applications In this course, emphasis is placed on research, projects, and field trips. Students should learn how and where the computer can be used.	Division 5 only	Senior Division: 60 hours	Computer Laboratory
Computer Logic In this course, logic trainers would be used extensively.	Division 3 only	Senior Division: 60 hours	Computer Laboratory
Computer Circuitry A course for those students who wish to learn how computer circuits perform their functions.	Division 2 only	Senior Division: 60 hours	Electronics Shop

Implementation

Possible Courses

To illustrate some of the possible courses, several are suggested in the course designation column of the chart on page 18 (opposite). In addition, teachers of Elements of Computer Technology could supplement the instruction given in several technical subjects. The following list indicates a few of the technical areas in which the computer is used:

Elements of Mechanical Technology
numerical control
automated drafting

Elements of Electrical Technology
computer-controlled power grids
communications: information coding and decoding

Elements of Construction Technology
critical path determination
automated drafting

Elements of Automotive Technology
parts inventories
suspension design

Graphic Arts
computerized composition

Industrial Physics
control instrumentation
trajectory analysis

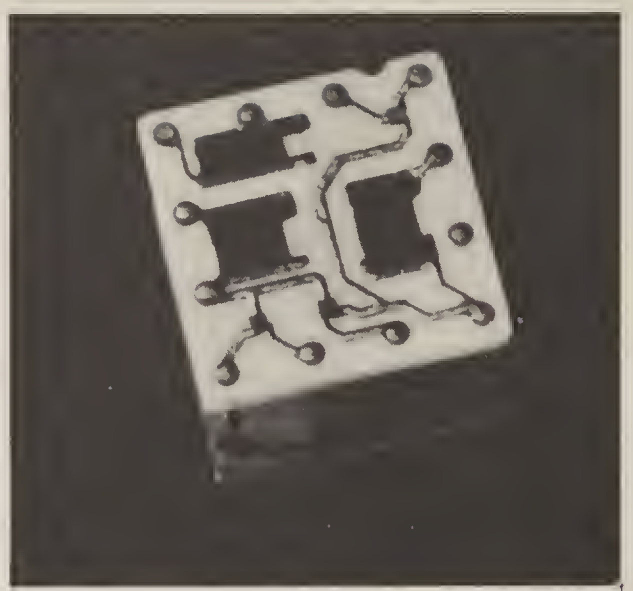
Industrial Chemistry
process control

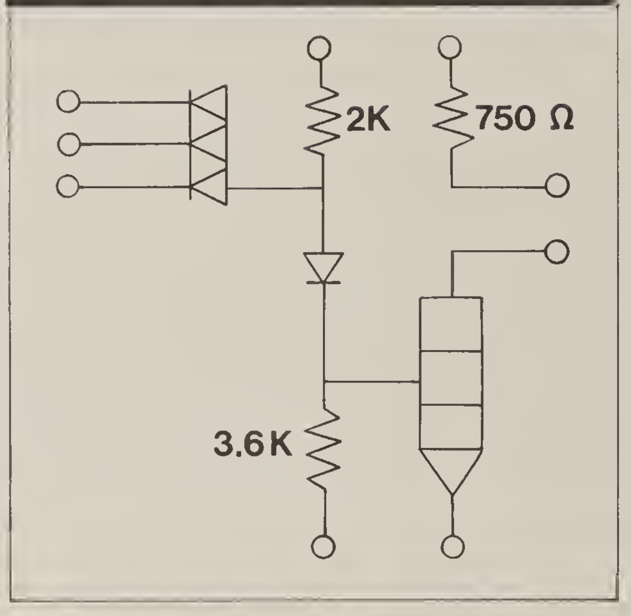
The teachers and students of non-technical subjects may also wish to use the computer laboratory and the special knowledge of the laboratory teacher(s). Obviously, the degree to which this is possible depends upon the flexibility of the administrative arrangements and the co-operation among the individuals involved.

Although it is quite possible that several teachers might work as a team in the presentation of courses within this guideline, most of the program could be taught by two individuals whose combined experience and skills include proficiency in electronics, programming, and computer logic. Proficiency in electronics might be supplied by a teacher of electronics whose broad knowledge of his subject either includes computer circuitry or could be expanded to include computer circuitry. Proficiency in computer logic and programming might be supplied by a teacher who has completed intensive studies in these areas or has suitable experience in the computer industry. Both should be aware of current computer applications and be familiar with peripheral and input-output equipment.

continued

Accommodation and Equipment





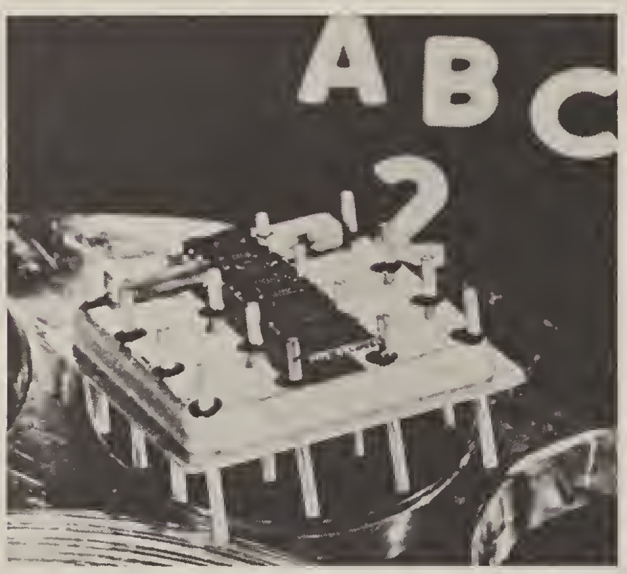
Ideally, to offer Elements of Computer Technology I or II, two rooms should be available: an electronics shop and a computer laboratory.

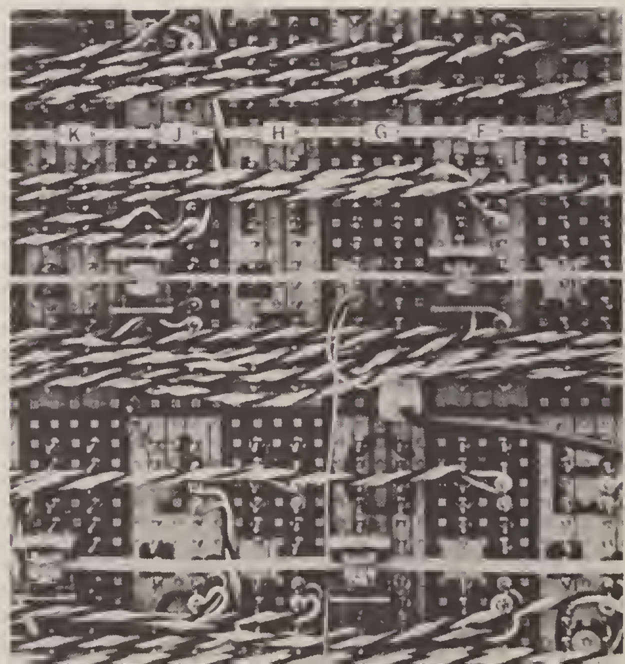
The electronics shop would be conventional in most respects. The usual equipment used in communications and industrial electronics would be supplemented by computer hardware to allow circuit construction and analysis.

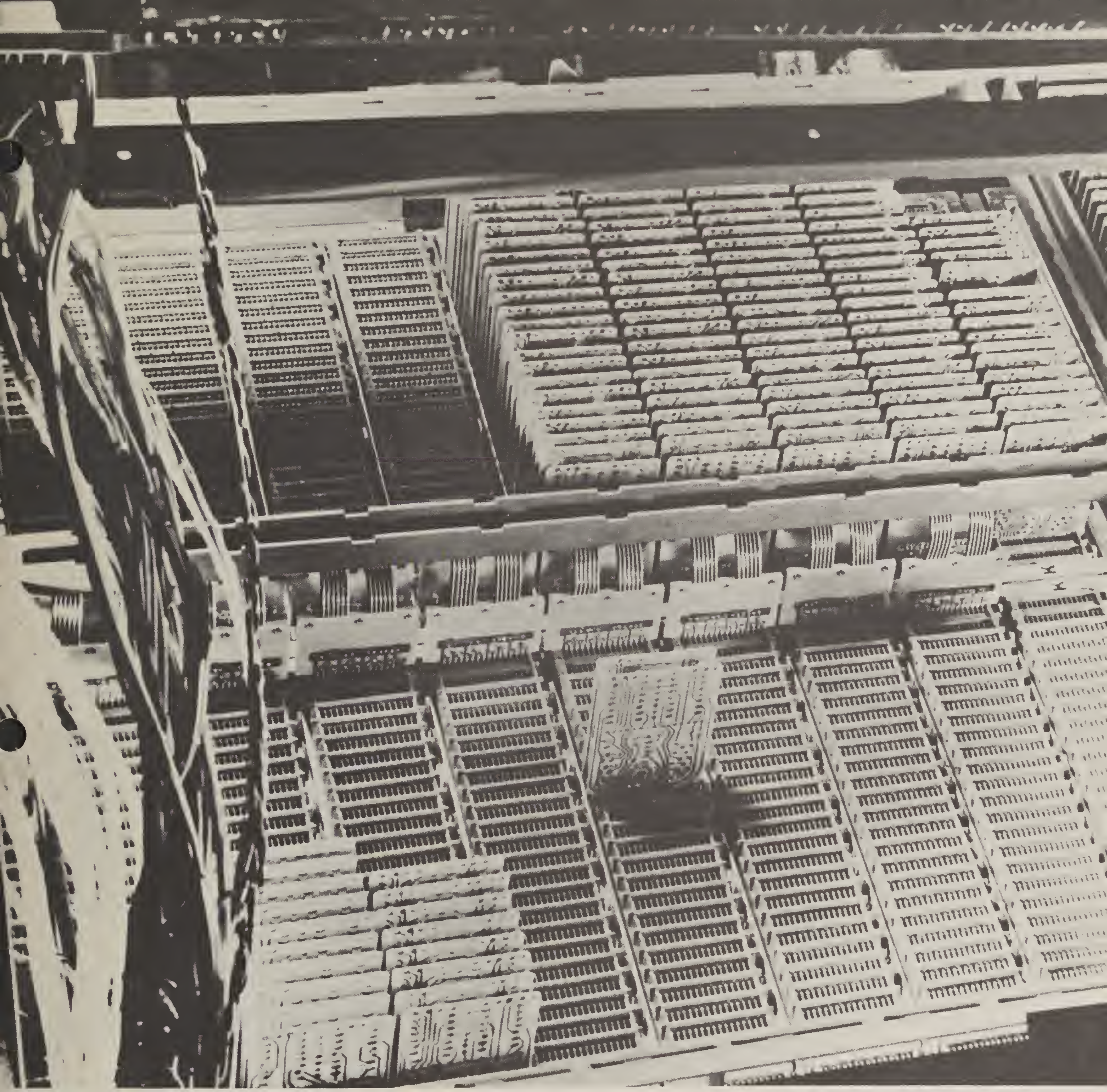
The computer laboratory should have the following apparatus:

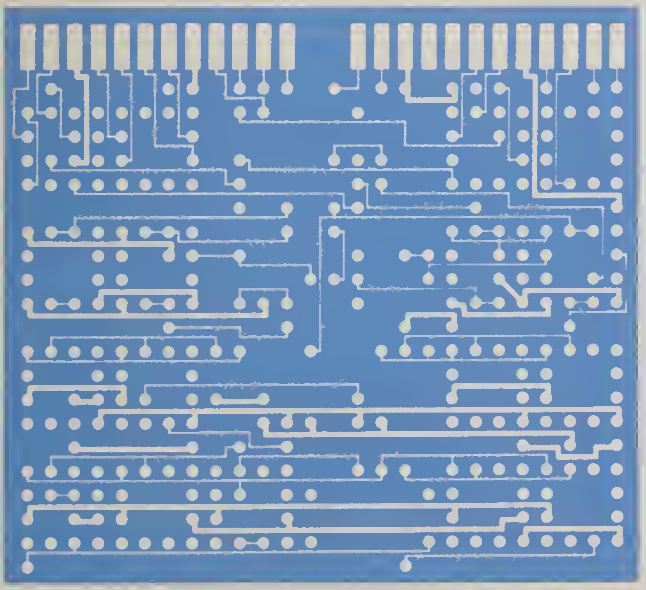
- several logic trainers
- a small computer as a teaching aid, to supplement logic trainers and permit hands-on experience
- measuring instruments, especially quality oscilloscopes
- electromechanical kits
- samples of peripheral equipment for dismantling, examination, and assembly.

In addition, a computer for processing student programs in higher level languages should be accessible. There are several ways of acquiring such access, ranging from a fixed annual charge per student to the purchase or rental of a larger computer.









Resources

Bibliography

Adelfio, S. A. *Principles and Applications of Boolean Algebra*. New York: Hayden Book Co., 1964 (Toronto: General Publishing Co. Ltd.).

The basic mathematical concepts involved in the development of logic systems are described in simple terms.

Alcosser, Edward; Phillips, James P.; and Wolk, Allen. *How to Build a Working Digital Computer*. New York: Hayden Book Co., 1967 (Toronto: General Publishing Co. Ltd.).

This book describes construction techniques for building an inexpensive computer. Component specifications are listed and step-by-step assembly instructions are provided. Programming is explained so that the computer can be utilized to solve actual problems.

Allen, Paul. *Exploring the Computer*. 1st ed. Reading, Mass.: Addison-Wesley Publishing Co. Inc., 1967 (Toronto: Addison-Wesley (Canada) Ltd.).

This is a programmed book for students who want a brief introduction to computers at the high school level.

Bartee, T. C. *Digital Computer Fundamentals*. 2nd ed. New York: McGraw-Hill Book Co., 1966.

This introductory text deals with the principles of digital computers. The latest techniques and devices are described.

Brayton, Jack. *Computers Self-taught Through Experiments*. New York: Howard W. Sams Inc., 1966 (Toronto: Thomas Allen & Son Ltd.).

Computer circuits and components are treated in a specific manner with practical projects supporting the discussion of theory. Care has been taken to select components that are available at low cost.

Davis, Gordon B. *An Introduction to Electronic Computers*. New York: McGraw-Hill Book Co., 1965 (Toronto: McGraw-Hill Co. of Canada Ltd.).

This is a programmed book for students who want a brief introduction to computers.

Flores, Ivan. *Computer Design*. Englewood Cliffs, N.J.: Prentice-Hall Inc., 1967 (Toronto: Prentice-Hall of Canada Ltd.).

This is a fairly complete text on all aspects of computer design. It covers the uses of transistor digital circuits in detail and is intended for the technical institute or junior college level.

Flores, Ivan. *The Logic of Computer Arithmetic*. Englewood Cliffs, N.J.: Prentice-Hall Inc., 1967 (Toronto: Prentice-Hall of Canada Ltd.).

This text is an advanced, up-to-date book on computer arithmetic units using parallel natural binary arithmetic.

Haag, James N. *Comprehensive Fortran Programming*. New York: Hayden Book Co. Inc., 1965 (Toronto: General Publishing Co. Ltd.).

This introduction to computer programming may be used as a self-teaching device. No previous experience with computers is assumed.

Halacy, D.S., Jr. *Computers: The Machines We Think With*. New York: Harper & Row, 1962 (Toronto: Fitzhenry & Whiteside Ltd.).

This book covers the history of computers from the discovery of the abacus through Jacquard and his use of punched cards in weaving to the latest developments and the enormous potential for the future. The author discusses in simple terms the basic theories and operation of digital and analogue computers, and shows them at work in business, industry, and education.

Hollitch, R.S., and Mittman, B. *Computer Applications*. New York: MacMillan Co., 1962 (Galt: Collier-MacMillan Canada, Ltd.).

This text reports new developments in the application and expanding uses of digital computers in management, business, engineering, and scientific research. It is useful for senior grades and teacher research.

Holmes, James F. *Data Transmission and Data Processing Dictionary*. New York: John F. Rider Inc., 1965 (Toronto: General Publishing Co. Ltd.).

This book defines more than 3,000 terms used in data processing, telephony, telegraphy, facsimile, and data transmission work.

🍁 Hull, T.E., and Day, D.D.F. *Introduction to Computers and Problem-Solving*. Toronto: Addison-Wesley (Canada) Ltd., 1969.

This book explains the function of a computer and shows how it can be used to solve a wide variety of interesting problems.

Jacobowitz, Henry. *Computer Arithmetic*. New York: John F. Rider Inc., 1962 (Toronto: General Publishing Co. Ltd.).

This book reviews the basic arithmetical operations of all positional number systems: the decimal, the binary, as well as other number systems that have found or are likely to find application in computers.

Jacobowitz, Henry. *Electronic Computers*. 1st ed. New York: Doubleday & Company, Inc., 1963 (Toronto: Doubleday Publishers).

This book is a comprehensive guide for self-study and review. The basic principles governing digital and analogue computers are well illustrated with diagrams, and a glossary of computer terms is included.

Maley, G.A., and Heilweil, M. *Introduction to Digital Computers*. Englewood Cliffs, N.J.: Prentice-Hall Inc., 1968 (Toronto: Prentice-Hall of Canada Ltd.).

This text attempts to answer such questions as: What is a digital computer technician? What must he really understand about logic, binary arithmetic, and programming?

Richards, R.K. *Electronic Digital Components and Circuits*. Princeton, N.J.: Van Nostrand, 1967 (Toronto: Van Nostrand Reinhold Ltd.).

This book explains how various components and circuits work. It compares the relative attributes of digital circuit components such as diodes, transistors, tunnel diodes, and superconducting devices.

Sippl, Charles. *Computer Dictionary and Handbook*. Indianapolis: Howard W. Sams Inc., 1966 (Toronto: Thomas Allen & Son Ltd.).

This is a comprehensive handbook for reference purposes.

Spencer, Donald D. *A Guide to BASIC Programming: A Time-Sharing Language*. Reading, Mass.: Addison-Wesley Publishing Co. Inc., 1970 (Toronto: Addison-Wesley (Canada) Ltd.).

This is a good introduction to computer time-sharing systems and the programming language.

Wilson, Robert A. *Optical Page Reading Devices*. New York: Reinhold Book Corp., 1966 (Toronto: Van Nostrand Reinhold Ltd.).

This is a reference survey of the important new developments in numerous types of information retrieval devices and equipment.

Film

🍁 *ABC's of Computers.* Canadian General Electric. (18 min.) colour.

This film provides a basic introduction to computers with some description of circuits.

ACCEL Automated Circuit Card Etching Layout. The U.S. Atomic Energy Commission. (20 min.) colour.

ACCEL is a computer program that designs printed circuit boards from data taken by clerks from engineers' drawings. The program outputs the schematic, parts list, printed circuit negative, assembly drawing, and hole drilling list.

A Matter of Time. UNIVAC Division of Sperry Rand of Canada Ltd. (15 min.) colour.

The film describes Univac's installation for the handling of reservation and ticket transactions, designed for British European Airways.

Computer for Apollo. National Aeronautics and Space Administration. (28 min.) b/w.

The film examines how the Apollo Guidance Computer works and how it is assembled.

Computer Logic, Part I, Binary Numbers. (Film # MN8969 — B). U.S. Navy Training Films. (14 min.) colour.

This film examines the meaning of logic and logic operations. A section on the binary number system explains serial and parallel coding, the binary coded decimal system, and the alpha numeric code.

Computer Logic, Part II, Logic Elements. (Film #MN8969—C). U.S. Navy Training Films. (20 min.) colour.

This film shows the function of logic elements. The following elements are explained: AND gates, OR gates, inverter, nor, delay and flip flops.

Computer Units (File # MN 8969 — D). U.S. Navy Training Films. (23 min.) colour.

This film explains the function of the five major units of a digital computer: input, storage, control, arithmetic, and output.

Frontiers in Computer Graphics. International Business Machines. (22 min.) colour.

The film demonstrates the use of display consoles in multi-programming environment.

International Business Machines 2250 Graphic Application Demonstration. International Business Machines. (18 min.) colour.

The film shows some aspects of man-machine communication through a graphic console. Eight engineering applications are displayed: beam loading, data reduction, schematic diagram generation, wire routing, analogue simulation, two-dimensional drafting.

Incredible Machine. American Telephone and Telegraph Company. (15 min.) colour.

The film illustrates how Bell Telephone uses computers in circuit design, graphics, and voice reproduction. It describes the functions of scientists, engineers, programmers, and artists when teamed with a computer to achieve interesting and unusual results.

Logic on a Chip. Radio Corporation of America. (8 min.) colour.

The advantages of integrated monolithic circuitry, such as increased speed, reliability, and lower cost are demonstrated. Manufacturing techniques for this circuitry are shown at RCA's plant in Needham, Mass.

🍁 *Memory Devices.* Bell Telephone Co. of Canada. (28 min.) colour.

Various storage devices used in computers are described and illustrated.

🍁 *Movies from Computers.* The National Film Board. (20 min.) b/w.

This film shows an application of computers to the production of animated films.

The Computer and Numerically Controlled Machine Tools. International Business Machines. (17 min.) colour.

Two programs for operating numerically controlled machine tools, AD-APT and AUTOSPOT, are demonstrated.

Photo Credits
IBM: p. 4, 10, 11, 12, 20, 21
Digital Equipment: p. 8, 14, 16